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ABSTRACT

This review incorporates 143 Brazilian science education research studies from the years 1972-1977. It is organized into five sections: curriculum studies, primary, secondary, and university level studies, and a conclusion (an overview of education in Brazil). Among the findings are the following. Science education research reports are communicated primarily through national conferences. The research is primarily directed towards the university level, and is dominated by studies in physics. The majority of the science education research is being conducted by a small number of universities. Graduate schools of education are contributing little science education research. Few experimental or comparative studies were reported in the science education literature; most of the Brazilian studies were course descriptions and reports on teaching innovations. (BB)

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A REVIEW OF SCIENCE EDUCATION RESEARCH IN BRAZIL

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A REVIEW OF SCIENCE EDUCATION RESEARCH IN BRAZIL

Summaries of research in science education provide educational researchers with valuable information. As Rowe and DeTure point out in their 1973 review, a research review should characterize the state of knowledge in science education, depict existing trends, identify areas for future investigation, and provide tentative solutions to problems that emerge from the literature. It might be added that comparisons of annual or biennial reviews are also important since they reveal changes in research priorities and methodologies from one year to the next.

A review of science education research conducted in a foreign educational system can also provide educators with valuable information. Apart from contributing to the growing body of acceptable knowledge about science teaching, an international research review can provide an overarching view of the stage in which the development of the research infrastructure that supports science education research is set. By analyzing the research priorities, problems, methodologies, and findings of studies reported in the

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literature, it is possible to obtain an accurate picture of the state of research in a foreign educational system.

A second contribution of an international research review is that it can, if properly organized, elucidate the structure, the underlying philosophies, and the problems and priorities of the national educational system. Often in educational systems ~~that~~ which adopt a policy of accelerated development, an emphasis is placed upon applied rather than pure research. Hence, research reports, position papers, and general contributions such as course descriptions, often deal with issues that address themselves to immediate and fundamental educational problems. An international review, therefore, can describe, either in explicit or implicit terms, the educational system in which the research was conducted.

Methodology

For the review, more than 1300 published documents, such as research reports, position papers, school course descriptions, and teaching and program innovations were analyzed and 235 documents that dealt with science education identified. From this number, 143 studies were ~~entered~~ used into this report. The documents were extracted from various sources: national education journals, dissertation abstracts, and abstracts of studies presented at the annual meetings of the

Brazilian Society for the Advancement of Science (SBPC) for the years 1972 to 1977, and the biennial meetings of the Brazilian Association of Physics (ABF) for 1974 and 1976. A total of eight national sources were drawn upon when compiling the list of studies.

Two criteria were established to determine if a study were appropriate for the review. First, the study had to deal with some aspect of the teaching of either a traditional science, such as biology, or an applied science, such as health education. Because Brazilian science teaching, especially on the primary and secondary levels, is perceived to play an important role in community development, this extended definition of "science" was thought appropriate. The second criterion was that a study had to be classifiable according to one of the following"research categories": descriptive research, such as fact-finding surveys, case studies, correlational studies, position papers, etc., experimental and comparative studies; and descriptions of science courses and teaching innovations. Thus, the terms "research" and "educational study", when used in this review, encompass a variety of published contributions on science teaching.

In response to some particularly vexing problems, several decisions were made which affected the character of the review. First, many of the abstracts that were analyzed failed to adequately provide information about the studies they were summarizing. Incomplete and vague data was quite common.

This difficulty, and the fact that the studies were not equally informative or generalizable, prohibited many studies from being reported in the review, or in the case of several studies that were, from being discussed with the degree of thoroughness that would have been desirable.

A second problem was that the majority of studies were conducted within a six year period, from 1972 to 1977. The fact that only 235 documents could be identified during this period, made it difficult to identify trends or significant historical developments in the research. As a result, most of the studies were discussed without reference made to the date they were conducted or published. There were, of course, exceptions, as when the date was considered essential for understanding the importance or for interpreting the findings of a study.

The final problem that required a solution arises from a peculiarity of educational research in Brazil. Approximately half of the studies discussed in the review were coauthored by as many as two to six individuals. ~~To~~ Therefore, to make the list of references at the end of the report manageable, it was decided that only the name of the senior author of a study coauthored by three or more individuals would be given in the reference. Furthermore, in the text of the review, only single authors and senior authors of coauthored articles would be cited. This measure was adopted in order to streamline the review which would have otherwise been overly large and

cumbersome. It should be added that in the reference section, the titles of the studies were translated from Portuguese into English in order to give a more accurate profile of the types of education studies currently being conducted in Brazil. The names of the journals, however, remained in Portuguese.

The review is divided into five sections: curriculum studies, research on the primary, secondary, and university levels, and a concluding section that gives an overview of education research in Brazil. In each of the sections an attempt was made to place the study within the context of the Brazilian educational system.

Curriculum Studies

Since the early 1960's several U.S. science curriculum projects such as the Chemical Bond Approach (CBA), CHEM Study, the Physical Science Study Curriculum (PSSC), the Intermediate Physical Science Curriculum Study (IPS) project, and the Biological Science Curriculum Study (BSCS), both the Green and the Blue Versions, have been used in Brazilian secondary schools. The first U.S. science curriculum to be introduced into Brazil was the CBA project, which was translated in 1957 by members of the Medical School of the State University of Sao Paulo (USP). Later, and in quick succession, CHEM Study, PSSC, BSCS (Green), and IPS were translated by the Brazilian Foundation for the Teaching of Science (FUNBEC) with funds provided by the Ford Foundation.

Part of the process of adopting foreign science curricula has involved adapting them to the specific environmental and socio-economic realities of the Brazilian school. This was the case for the BSCS Green Version which was modified to include descriptions of the indigenous fauna and flora of Brazil. More recently, Paschoale (92) and Amaral (6) describe a three year project at the University of Sao Paulo (USP) to render the Earth Science Curriculum Project (ESCP) suitable for a first year introductory college course in Geology. In the project special 8 mm. films, slides, and photographs of the Brazilian landscape were incorporated into the curriculum package. In addition, inservice teacher training courses were instituted to instruct 21 professors who serviced a combined

enrollment of more than 2000 students in the proper use of the curriculum materials.

It should be noted, however, that the efforts of the Geology Department of USP to modify the ESCP program does not reflect a broader trend of continuing adaptation of foreign curricula in Brazil. On the contrary, the ESCP adaptation project should be considered a vestigial practice of an educational policy that is largely defunct. One of the many reasons for this change of policy and a corresponding increase in self-reliance on the part of Brazilian curriculum developers, is that new experimental findings, such as that observed by FUNBEC in a formal evaluation of the BSCS materials (BSCS, /145), have shown that foreign curricula often do not result in significant student gains as anticipated. With the assistence of Hulda Grobman, Richard Tolman, and James Robinson, FUNBEC evaluated both the teachers and the students of 300 classrooms that used the BSCS Green Version text and laboratory units, and observed the following: (1) No significant differences were found between the students of the experimental and the control groups, and no interaction effects were detected. It was also concluded that the Class Activities Questionnaire which required students to analyze the instructional setting of their classrooms was not appropriate in Brazil for cultural reasons. (2) After a three week inservice teacher training course the experimental group teachers felt that the ideal biology class should provide oppurtunities for student

discussion more so than the control group teachers who remained indecisive on this point. The investigators felt that this was a significantly positive outcome for such a short training program.

Such findings, both formally and informally obtained, have generated numerous criticisms like those voiced by Caniato (26) who writes that many imported science curricula are too costly for Brazilian schools and unsuitable for Brazilian classrooms since teachers and students are not prepared to experience the teaching methods and technologies the curricula espouse. Consequently, indigenous curricula that are appropriate for the teaching reality of the Brazilian schools should be developed. As an example of the types of curriculum needed, Caniato describes the Brazilian Project for the Teaching of Science (PBEF) which consists of five units, each of which contains material organized into progressively increasing levels of difficulty. Students are first exposed to simple verbal explanations of physics concepts; later, they explore the same concepts in more detail. Finally, mathematical explanations of the concepts are presented. The spiral organization is considered especially apt for the varying levels of student performance found on the secondary level. Another innovation of the PBEF curriculum is that laboratory activities are conducted with inexpensive and easily fabricated materials.

Santos (103, 104), Almeida (2), Pacca (88), and the PEF Curriculum Development Group (58) describe efforts at USP to

developed the Project for the Teaching of Physics (PEF) curriculum. The program, which consists of two volumes of mechanics and one volume each on electricity and electrodynamics, was designed for the high school student who does not continue his education beyond the secondary level. The curriculum is billed as partially self-instructive since it consists of a text that provides students with the resources for independently conducting experiments and completing exercises at the end of the chapters. Inexpensive laboratory materials are included, as well as supplementary texts on topics such as "The Role of Science in Society," "The Theory of Relativity," "Patterns of Measurement," and "Entropy." Like its American cousin, Project Physics, PEF focuses considerably on the humanistic side of science.

Evaluations were performed to determine the reaction of students and teachers to the PEF materials. Quintas (95), in a study part of which involved a nonstatistical comparison of the performance of groups taught by the PSSC and PEF curricula, found that when comparing the results of the two groups on selected test items in "knowledge" and "comprehension" as defined by Nedelsky in Science Teaching and Testing, the groups did not significantly differ in their scores. Considering the prestige alotted to the PSSC curriculum, this might be interpreted as a victory for PEF. Pacca (86), on the other hand, found that the content matter within the PEF units did not always provide students with the information they required for

correctly answering questions at the end of the PEF units. Even though Facca does not say so, it appears that his study was one of the formative evaluations conducted during the development of the PEF text.

In a more recent curriculum project, the Study Group on the Technology of Teaching (123) of USP reports on the Auto-Instructional Physics Project (FAI). The FAI curriculum consists of a set of five programmed texts that begin by covering topics such as the elementary laws of movement and concepts of energy, and ends by discussing complex movements and the basic notions of modern physics such as electromagnetism. The FAI group describes its efforts to evaluate the secondary school curriculum in 26 schools servicing more than 6000 students. The results of the evaluation were not presented in the abstract. Nevertheless, if the FAI evaluation project is considered in terms of the evolving capacity of Brazilian curriculum developers to evaluate indigenous curricula, then the project can certainly be considered a success. As for FAI success in the schools, Araujo (10) found that in the Federal Technical School of Bahia, 5 classes composed of 125 students positively benefitted from the curriculum in terms of achievement and motivation. No data were presented to substantiate this conclusion. Finally, Gevertz (54) reported on a project in progress at the time the abstract was published, that attempted to determine the "isomorphism" or level of congruence between the FAI programmed content and the methods used to teach the material. Gevertz does not present

any data in ~~his~~ her abstract nor does he make clear whether the evaluations were conducted during the development of FAI.

Vocational Science Curricula

Several particularly innovative curriculum projects have been developed to compliment the standard science curriculum projects described above. In 1974, the Program for Expanding and Improving Teaching (PREMEN) of the Brazilian Ministry of Education (MEC), in conjunction with the CENAFOR Foundation, an organization that sponsors inservice teacher training courses for teachers of vocational secondary schools, promoted the development of the Applied Physics Project (PFA). Representatives of the CENAFOR Foundation (51) write that the new curriculum was specifically developed for physics courses within the vocational tracks of the secondary schools. The PFA text consists of 7 units comprising 32 modules which can be juxtaposed in varying sequences depending upon the learning needs and rates of the students. The salient characteristic of the curriculum is that it can be used in 14 different vocational specialities, some of which are Ceramics, Mechanics, Metallurgy, Chemistry, Telecommuncations, and Agronomy.

A similarly oriented physics curriculum is described by Almeida (4). The Project for Professionalizing Education (PEPE) is a collaborative effort by industry, governmental agencies, and the Department of Secondary Education of the MEC to design a physics curriculum appropriate for vocational education in the high school. Basically, PEPE consists of material for 560

hours of classroom instruction on topics such as mechanics, electrodynamics, electrotechnics, electronics, and instrumentation and telecommuncation.

Santos (106) and Maniakas (72) write about a general science curriculum developed by FUNBEC and MOBRAL, the Brazilian Adult Literacy Program. The FUNBEC/MOBRAL science curriculum is designed for adults who have successfully completed the MOBRAL literacy program. The curriculum, which is part of a post-literacy general education program, consists of a student text, a teachers manual, and inexpensive laboratory materials.

Science Kits

Brazilian efforts to construct indigenous science curriculum materials have not just been confined to creating texts, manuals, and laboratory materials. During the past 25 years Brazilian science educators, in reaction to the theoretically-oriented teaching that chracterized many Brazilian science classrooms, have been developing inexpensive science kits which can be purchased on the commercial market or through official educational channels. Raw (148) writes that as early as 1952 chemistry kits were fabricated in the Medical School of USP. Included in each kit were chemicals that were obtained from local industries, laboratory materials, and a "journal" giving instructions on experiments that could be conducted with the materials. The entire set cost $20.00 (US). A subsequent development was a ~~$2.00 (US)~~ 25¢ US each "pocket book kit" which contained inexpensive materials and instructions

on experiments, some of which were entitled "Osmosis", "Making Nylon", "Acids and Bases", Chromotography", "Biochemistry of the Gene", and "How Long Does a Chemical Reaction Take ". Maybury (147), in his description of technical assistance programs in Brazil, observes that in 1961 and 1962 FUNBEC developed science kits for general science courses. Later, in 1969, FUNBEC designed and disseminated science kits for the then existing junior (ginasio) and senior (colegio) high schools. The kits and accompanying texts treated topics on nutrition, personal hygiene, public health, and agriculture. Finally in 1971, FUNBEC, in collaboration with Editora Abril, a Sao Paulo publishing firm, developed 50 science kits, each of which contained a biography of a famous scientist, an experiment for which he was known, and simple laboratory materials. Instructions for both the teacher and the students were also included (Escola, 144). While these kits, sold in all kinds of stores, have been very popular the kits were designed for the secondary school science class, they were also used in teacher training programs. Santana Filho (101) reports on a laboratory teaching methods course at the University of San Carlos (UFSCAR) which involved students in performing the kits' experiments and in suggesting improvements on both the materials and the techniques needed to master them. Later, the students' developed their own kits.

Several years after the 50 item set was developed, Gatti (52) conducted an evaluation of the set and found that an experimental group of students who performed the activities

contained in the Newton, Lavoisier, Einstein, and Volta kits, demonstrated significantly more knowledge of the content related to the experiments than a control group of students who received only lectures on the content. In addition, the experimental group demonstrated significantly more motivation in their studies than did the control group.

While it appears that the science kit "curriculum movement" has diminished in importance since 1971, many science educators still adopt the kit concept as a means for ameliorating difficulties encountered in their instructional settings. Ferreira (46), for example, relates how individual secondary school students constructed their own geometrical optics kits to study the refraction and reflection of light on planes, and concave and convex surfaces. Tolentino (134) discusses kits containing models of atoms, molecules, and crystals for studying the concept of magnetism. Alves Filho (5) and Sekkel (110) write about a particularly innovative use of science kits in the theoretically-oriented physics classes of USP. The materials contained in the kits were assembled from old and unused physics laboratory equipment and were supplemented by a teacher's guide that explained how to use the materials, how to correctly perform a demonstration, and how to lead a group discussion. As Alves Filho notes, the kits were specifically developed to encourage normally reticent teachers to illustrate theoretical concepts with well-staged demonstrations.

Summary

The origins of the Brazilian curriculum reform movement can be traced to initial efforts by Raw and others in the early 1950's to introduce the experimental method into secondary school science courses by means of science kits. In the early 1960's the kit approach was complimented by a movement to adopt and adapt foreign science curricula for Brazilian schools. In the 1970's national science curricula were developed to replace the foreign curricula that were found inappropriate for many of the secondary schools. One of the characteristics of this stage of the reform was that the majority of the new curricula were physics curricula; no mention was made in the literature of formal efforts to develop biology and chemistry curricula and disseminate them nationally.

Earlier in this section it was pointed out that the influence of foreign science curricula has considerably diminished. However, it should be recognized that the adoption of foreign science curricula has played an important, if not crucial, role in the evolution of the Brazilian curriculum reform moviment. This argument is made by Carvalho (27) who observes that while PSSC was seldom adopted by physics teachers in Sao Paulo due to inherent limitations in the school environment, the PSSC program did have an impact on university efforts to provide science texts and materials for secondary schools. Carvalho notes that the philosophy, development, and structure of PSSC

affected the Brazilian curriculum movement by introducing (1) the idea of formatively evaluating curriculum materials as they were being developed, (2) the notion of convening secondary and university professors, scientists, and technicians to develop science curricula, and (3) a new philosophy of science teaching which emphasized the active participation of the student in the learning process. In regard to this final contribution, Carvalho notes that PSSC has made Brazilian educators aware that physics can be portrayed as a continuous process of inquiry, has marked clearly the difference between science as a source of information and technology as an application of information, and has promulgated the notion that physics possesses an inherent structure that can be discovered by the student.

Research on the Primary Level

Prior to 1971, the Brazilian primary school consisted of four grade levels that were free and compulsory for all children between the ages of seven and eleven. Reform Law 5692, however, lengthened the four year cycle to eight years and legislated that by 1980 the primary school would be free and compulsory for all children between the ages of seven and fourteen. Law 5692 also allocated more responsibility in curriculum matters to each of the twenty-two state departments of education and more autonomy to the individual primary school

in adjusting its curriculum to the particular exigencies of the environment and community it services. Concerning classroom teaching, the most important directives of the law were those that increased the discretionary powers of the teacher in selecting the content and methodologies he deemed most important for achieving course objectives.

The authors of the 1971 reform law took special pains to emphasize the pivotal role of the school in promoting social change within the community, especially in the impoverished communities of the interior where a primary or secondary school is often perceived as a symbol of state or federal commitment to socioeconomic improvement. Law 5692's health directives, for example, clearly project an image of the school as a community action center. The 1971 law, and a subsequent official clarification (Garcia, /151), suggest that projects should be ~~mounted~~ organized in the school to improve health, nutrition, and sanitation practices in the community. These projects were to be organized and implemented by the combined efforts of teachers, students, school administrators, community leaders, and most importantly, the students' families.

Unfortunately, the literature shows that the Law's expectation that teachers and community leaders collaborate on community-school health projects is unrealistic when one considers the general preparation of the primary school teacher. This is the finding in a study be Serbino (111) who conducted a survey of teachers in the first four grade levels of the

primary schools of Botucata, and by Melo (76) who conducted a survey of teachers in an unidentified municipality of the state of Sao Paulo. Both researchers independently found that, contrary to the expectations of Law 5692, teachers were not collaborating with doctors, dentists, hospital and health officials, and the students' families in organizing community-school health projects. While neither author attempts to explain the reason for this situation, other researchers apparently have pinpointed the main obstacles to implementing the projects. In independent local surveys, Cavalcanti (34) and Castelan (33) found that the majority of the primary school teachers they interviewed did not possess sufficient knowledge of the nutrition principles they were supposed to teach. In particular, Castelan observed that in the prosperous south-eastern state of Rio Grande do Sul, many of the primary schools investigated not only lacked personnel for teacher personal hygiene and nutrition, they also lacked material resources.

The incongruity between the aspiration of the reform and the reality of the Brazilian school system regarding health education, appears to be symptomatic of a larger failing

of the reform. This is clearly underscored by Assuncao (14). In a survey conducted in the northeastern state of Bahia, 81 primary school science teachers were interviewed to determine if they were executing the various directives of the reform. Assuncao found, as many educators had already surmised, that the reform was not being implemented in the schools because, among other reasons, the teachers were not aware of the reform law, or did not fully understand it. More ominous was the fact that in many cases where the teachers did understand the law and tried to implement its directives, they often found themselves faced with the indifference of either their supervisors or their colleagues. These difficulties, and an omnipresent dearth of materials and an innate resistance to change in the teaching body, has rendered the reform ineffectual in many primary schools of Brazil.

Fact-Finding Surveys

Among the studies reviewed for this section several describe the state of science teaching on the primary level. According to Law 5692, science teaching in the first four years of the primary school is oriented primarily towards developing science-related abilities. Some science curriculum developers (146) have identified abilities such as observing, classifying, ordering, measuring, analyzing, and formulating hypotheses, just to name a few, for these initial years. No formally organized theoretical content is transmitted during

this period. In the final four years of the primary school, the development of scientific abilities continues; however, general science content is introduced to compliment the program to develop the science abilities. Of course as would be expected, many teachers still cling to traditional science curricula and teach science as in the pre-reform days.

Research on the primary level is very scarce, however several studies have been found that shed light on the methods of science teaching during the primary school years. Echenique (43) interviewed 16 professors and an unspecified number of eighth grade students from 6 primary schools in the city of Santa Marta and found that (1) the "scientific method" was not being taught properly in the schools, (2) the students' achievement in science was significantly related to the"science vocation" of the teacher, and (3) scientific "experiences", presumably laboratory activities, were not being included in the science programs. No further information was presented in the abstract.

Echenique's findings are somewhat contradicted by Simioni (120) who in a survey of primary schools in Bauru, in the state of Sao Paulo, found that 60 percent of the schools sampled had equipped laboratories. Also,75 percent of the teachers interviewed included some form of laboratory activity in their teaching programs. Apparently, science professors of the same school were sharing the same laboratory facilities. Furthermore, 77 percent of the students interviewed in the study had at

some time participated in laboratory activities. Of this number 72 percent indicated that the chemistry laboratory sessions were interesting, while only 34 percent and 24 percent found the physics and biology laboratories respectively so. As in the previous study, the abstract did not present information on the schools, the teachers, or the students sampled.

Palma Filho (90), reporting on the results of a questionnaire sent to 35 science teachers in 20 primary schools of Sao Paulo, found that 27 percent of those interviewed did not use a text-book when teaching and 75 percent felt that a teachers guide, which many did not possess, was of paramount importance in their teaching. No further findings of significance were reported.

Finally, an interesting pair of studies which demonstrate the type of commitment and creativity being generated to improve science teaching on the primary level is presented by Pfromm (93) and Gevertz (53) who describe the Tele-Escola Project. The Tele-Escola Project, which is funded and administered by the State Department of Education of Sao Paulo, the Padre Anchietta Foundation, and Channel Two Television of Sao Paulo, attempts to improve student performance in science and mathematics by means of a series of televised lectures. Gevertz describes how 50 televised lessons were transmitted to 50 fifth grade classes containing more than 3000 students. Each lesson was coordinated with the science texts used in the classes. Also, before and after each transmission a pre and post test were administered to determine if the students significantly benefitted from the lessons. Preliminary findings seem to show that this is the case.

Summary

The studies reviewed in this section point out several problems of science teaching on the primary level. The most glaring is the apparent inefficacy of Reform Law 5692 in many parts of Brazil. Even though the reform has ambitiously sought to improve teaching on the primary level, large segments of the teaching populace are ignorant of the law or unable to comply with its directives. More specifically, the literature shows that in the area of science teaching there is an incongruence between what the law expects from teachers, especially in regards to health education, and what the teachers are willing or able to do.

Another problem identified in the review is the incomplete use made of the laboratory in the primary school. This has been shown to be a symptom of a larger deficiency in textbooks, teacher guides, and didactic materials that afflicts the primary school system. However, when reflecting upon these findings, one should keep in mind that the aforementioned surveys were conducted in urban centers of the more affluent states of Brazil. Considering the fact that the majority of the primary schools are poor, rural, one-teacher schools located in the interior of the country (Havighurst,154), we can conclude that the difficulties of science teaching pointed out in the review are much more severe than the studies would at first seem to indicate.

Research on the Secondary Level

Traditionally, the Brazilian high school has been preparative rather than formative. Prior to the 1971 reform, the Brazilian secondary school served as a conduit for students on their way to a university education. In fact, this elitest function was officially sanctioned and encouraged by the 1961 Law of Directives and Bases which stipulated that select high schools could oriente the final year of coursework towards preparing students for the college entrance examinations. Unfortunately, the 1961 law gave little thought to the student who did not intend to further his education beyond the secondary level.

Reform Law 5692, however, changed the general character of the Brazilian secondary school. In fact, the 1971 law reversed the role of the Brazilian high school in relation to what it once had been. With Law 5692, secondary school education became formative rather than preparative. The post-reform high school was legislated to provide vocational training courses, in addition to the standard academic courses, for each student enrolled on the secondary level. The MEC's reasoning for advocating this dramatic transformation was that such a policy would ensure that noncollege-bound students could successfully enter the labor market upon finishing their secondary education.

The post-reform Brazilian secondary school was legislated to consist of three grade levels, and in some cases as in the

normal schools that prepare primary school teachers for grades five to eight, four levels. In the first year of study students are exposed to a wide variety of academic courses, some of which are biology, chemistry, physics, and mathematics. During the next two years, the students are immersed in specialization or vocational courses that prepare them for one of fifty-six professions, examples of which are mechanics, meteorologist, translator, tour guide, and petrochemist. When appropriate, additional science courses are offered in the specialization programs that are "scientific" or "technological" in nature.

The 1971 reform has not been totally successful on the secondary level. This is pointed out by Tolentino (132) who writes that many post-reform high school chemistry teachers still select and organize course content with the objective of improving student performance on the college entrance examinations. As a consequence, scant attention is given to either the logical structure or the social significance of the material. Tolentino decries this marked failing of chemistry teaching in Brazil and urges that a special effort be made to render science courses more relevant, especially for the large number of students who do not pursue a university education. More specifically, he exhorts chemistry teachers to supplement traditional textbook teaching with lectures on technology, toxicology, ecological chemistry, biochemistry, and the chemistry of foods.

Suggestions have also been made for improving science

teaching in the final two years of the secondary school sequence. Vasconcelos (139), for instance, avers that science teaching in vocationally-oriented school programs, especially those training machinists and electricians, should emphasize hands-on activities whenever possible. He urges that in the spirit of the 1971 reform, the content and methods of science courses be programmed to reflect the socioeconomic reality of the community.

It appears, however, that science teaching in many of the secondary schools offering professionalization courses is not as Vasconcelos would envision it. This observation is supported by Souza e Silva (121) who concludes, on the basis of interviews with physics teachers of state high schools where professionalization cycles have been instituted, that the quality of physics teaching is on the decline. The reason for this, Souza e Silva claims, is that many high schools do not have laboratories or trained personnel to man them. Also, teachers are plagued by low salaries, and this innevitably is translated into poor student performance. Souza e Silva supports his assertions by noting that in the federal and private high schools where teachers' salaries are generally higher than those of state high schools, student performance is "better". It seems, however, that the correlation between a teacher's salary and student performance was logically derived rather than statistically verified.

Suggestions such as those of Tolentino and Vasconcelos

reflect a strong social change orientation in an educational system that is grappling with the myriad problems of accelerated development. Science teaching in such a context, it is often argued, should administer to the needs of the community. An appropriate example in which the school, and invariably science teaching, contributes to community development, is the system of vocational secondary schools which was in full operation by 1945 and which continues today. The vocational secondary schools, which service approximately 25-30 percent of the secondary school populace (Havighurst,53) were instituted to train students in one of four areas: primary teaching for grades one to four, agriculture, commerce, and a technical/vocational trade. The schools clientele is noncollege-bound students.

Both prior and subsequent to the 1971 reform, the vocational high school was designated to play an important role in national development. This is clearly emphasized by Veleda (141) who argues that the agricultural high school is essential for rural community development. By preparing technicians for rural areas it ensures that agricultural productivity increases and, as a consequence, the standard of living. The extent to which these schools are truely contributing to rural development is discussed by Junquiera (65) who surveyed 103 agricultural high schools throughout Brazil. Junquiera found that a mere 1 percent of the total secondary school population for the year 1973 was enrolled in

these schools. The majority of students were found to be male and one-third were of urban origin. While Junquiera does not say so in the abstract, it appears that the small number of agricultural high schools is having little effect upon rural community development efforts. Marques (73), in a study that investigated the nature of teaching in agricultural high schools, gives weight to this conclusion. Marques interviewed an unspecified number of teachers in agricultural high schools and found that many did not possess a university degree. Also, many were strapped by low salaries and thus forced to work at a second job. Marques concludes that these facts, along with an omnipresent job insecurity, has prohibited full faculty integration and the introduction of curricular innovations in the schools.

Fact-Finding Surveys

The research literature on the general nature of science teaching at the secondary level is sparse, yet there are several authoritative studies that present a revealing picture of how science is taught in the Brazilian high school. One of the most illuminating is a study by Carvalho (27) who, in 1975, surveyed 103 physics teachers from 59 secondary schools in Sao Paulo. The major findings of the Carvalho survey can be summarized as the following: (1) Many teachers did not have a university degree. Approximately 32 percent of the teachers sampled were enrolled in an undergraduate university program

at the time of the study. While no definitive figures are available, teachers without undergraduate degrees are a ubiquitous phenomenon, especially in secondary schools located in the interior of the country. The MEC, of course, requires that a high school teacher possess a university degree. (2) The teachers were relatively inexperienced. In sao Paulo, 47 percent of the teachers had been certified within 5 years of the date of the survey, and 17 percent within 6 to 10 years. (3) Job security was highly tenuous. An overwhelming 84 percent of the teachers were contracted for one year while only a scant 2 percent were contracted on a permanent basis. (4) A sizeable proportion of teachers were overworked. At least 33 percent of the teachers taught more than 40 hours per week. Approximately 17 percent taught between 31 and 40 hours. Carvalho, reflecting upon these figures, argues that a science teacher saddled with such a heavy teaching load cannot possibly prepare and evaluate his course effectively. (5) Many teachers had second jobs. Carvalho found that 43 percent of the teachers were employed in more than one school. A related phenomenon is that 60 percent taught science courses other than physics. However, this figure may be misleading unless one observes that 25 percent of the teachers were not certified or planning to be certified in physics. The members of this group were specialized in mathematics and chemistry. (6) In general, physics classes met few times during the week. In the first and second year of high school, 54 percent of the schools reported that

physics classes met only 2 hours per week, while 30 percent met three hours per week. In the third year the number of hours increased: 17 percent of the schools reported classes meeting 3 hours per week, while 57 percent reported classes meeting 4 hours per week. (7) A large number of physics courses did not include a laboratory program. Carvalho found that 66 percent of the schools sampled did not program even one physics laboratory session during the entire three year secondary school sequence. (8) Many teachers did not use a textbook. Twenty-two percent of the teachers did not use a physics text. Carvalho suggests that this practice might be due to the fact that many of the physics texts are experimentally oriented and thus require teachers to schedule experimental activities with which they are unacquainted. This observation might also explain why only 8.8 percent of the teachers sampled used the PSSC text, even though PSSC is promoted in the teacher training programs of USP. (9) The teachers valued the inquiry method of teaching. When asked to comment upon the primary objective of physics teaching, 54 percent of the teachers responded that developing a student's scientific spirit, i.e. his reasoning and critical abilities, as well as an inquisitive attitude, was more important that either preparing him for the university or for fashioning him into a scientifically literate citizen who will contribute to social progress. For an educational system devoted to social change, the adoption of an inquiry ideology in lieu of a developmentalist ideology is indeed an interesting and somewhat provocative finding.

In 1971, four years before the Carvalho study, Serpa (113) conducted a survey of physics teachers from 14 high schools in Salvador, the capital of the northeastern state of Bahia. In relation to the overall number of physics teachers in Salvador, this sample accounted for 40 percent of the teaching population. Serpa's study was almost identical to that of Carvalho and yielded similar, though somewhat more favorable results for Salvador. For instance, it was found that only 32 percent of the Salvador teachers did not have a university degree and that 48 percent were contract for more than one year. Only 24 percent of the teachers moonlighted. Also, 33 percent of the schools reported no laboratory programs while 79 percent of the teachers stated that they used the PSSC text. Why Serpa's study yielded more positive findings than Carvalho's study is an interesting question, especially when one considers that there exists a consensus among most Brazilian science educators that high school physics teaching in Sao Paulo is the best in Brazil.

Serpa did provide information about physics teaching on the secondary level that was not provided by the Carvalho survey. More specifically, Serpa ascertained that his teachers were young: 74 percent were thirty years old or younger. Also, class size was generally small: 59 percent of the teachers reported classes numbering 20 to 20 students and 21 percent reported classes of less than 20 students. While Serpa does not say so, the low number of students per class might be attributed to

the fact that many physics classes are programmed for the morning, afternoon, and evening shifts in the secondary school. Thus a large number of sections results in a reduced number of students per section. Another significant finding is that even though all of the schools surveyed reported having a laboratory in the school plant, laboratory equipment was apparently scarce. Approximately 56 percent of the schools reported laboratory teams of four or more students. Another indication of scarce resources is that 35 percent of the laboratory activities were teacher "demonstrations".

Carvalho's and Serpa's findings on the incomplete use of the laboratory in high school science courses is confirmed by Augusto (15) who interviewed 500 chemistry students from state high schools in the city of Sao Paulo. Augusto found that while 80 percent of the students enjoyed chemistry, felt motivated by the chemistry courses, and indicated a preference for laboratory activities, they usually experienced expository teaching in their classes.

The surveys of Carvalho, Serpa, and Augusto paint a generally glum picture of laboratory teaching on the secondary level. If we consider that their surveys were conducted in the cities of Sao Paulo and Salvador, and not in the small towns of the interior where many of the secondary schools are located, the situation appears much more serious than these studies would seem to indicate. The extent of the difference in science teaching between the urban and the

rural secondary school is as not yet fully determined. However, we are given some idea in studies like that conducted by Sander (156). Sander surveyed 94 academic secondary schools in Porto Allegre, the bustling, modern capital of the industrialized southeastern state of Rio Grande do Sul, and in selected big cities and small towns of the same state. Among his many findings, Sander discovered that while all of the Porto Allegre schools and 95 percent of the big city schools reported having laboratories, only 60 percent of the small town schools could say the same. Furthermore, between 40 and 50 percent of the laboratories in the three types of schools were poorly equipped. This figure, however, is deceptive for it was found that the small town schools reported only 12 percent of their laboratories in good condition. If we extrapolate these findings to the poor schools of the interior of the more underdeveloped western, northern, and northeastern states, like Bahia where Serpa's study was conducted, the dearth of laboratory and didactic materials is indeed ominous.

Summary

In this section of the review, several problems endemic to science teaching on the secondary level were discussed. Among the most significant are the following. First, science teachers are underpaid. Serpa (115) notes that in Salvador, Bahia, a high school physics teacher

must often teach 40 or more hours per week to earn a salary that is equivalent to six times the minimum salary. This amounts to $330 (US) a month. In an economy that is as high priced as New York City, this salary is clearly insufficient. Second, science teachers are overworked. To compensate for low salaries teachers must often assume heavy teaching schedules, moonlight, and teach extra science and non-science courses in their schools. As some educators have pointed out, the average science teacher does not have the time nor the inclination to introduce new innovations into his classroom. A third problem is that many teachers are under short-term contracts. This situation also vitiates against course innovations and it inhibits full faculty integration. Finally, laboratory facilities are inadequate. As shown in the surveys of Sao Paulo and Salvador, between one-third and two-thirds of the schools sampled did not have a laboratory program, or when they did, the laboratory sections were likely to be overcrowded. It was also pointed out that these problems affect not only the academic and the professionalization high schools but the vocational high schools as well.

Research on the University Level

The Brazilian university system is of recent origin. Since 1940 the number of federal universities has increased from five to its present number of thirty-two. This number is of course augmented by the various state and private universities scattered throughout Brazil's twenty-two states. Not surprisingly, the increase in the number of universities during the past three decades has been accompanied by a corresponding increase in the demand for higher education by secondary school students. Unfortunately, this demand has far outstripped the resources of the university system and has thus resulted in a small, select number of students being admitted to the universities while the vast majority are refused.

College Entrance Examination

Acceptance by a Brazilian university typically depends upon a student's performance on the exame vestibular, or college entrance examination. In 1957, the federal government standardized the content areas of the vestibular examination while at the same time allocating the right to the universities to introduce additional subjects if so desired. The examination format was also left to the discretion of the individual universities. The science disciplines legislated to be included in the examination were physics and chemistry for the Science and Technology specialties, and physics, chemistry, and biology for the Biomedical specialties. No science courses were required for the Human and Social Sciences, Arts, and Letters

specialties.

The vestibular examination has been the subject of several interesting studies like that of Sanocki (100) who analyzed the physics test of the 1972 vestibular examination of USP. The test, which was composed of 10 items, each of which presented a problem and a series of questions requiring numerical solutions, lasted three hours and valued a total of 100 points. In his analysis, Sanocki found that the overwhelming majority of students obtained disappointingly low scores: a total of 4342 students obtained scores between 0 and 20 points while only 315 obtained scores of 20 points or higher. This latter group, which included both medium and high scores, accounted for 7 percent of the total number of students who took the examination. Sanocki concluded that the test was too difficult for the majority of the students and thus did not accurately reveal how much physics they really knew. He further noted that for all of the tests comprising the vestibular examination, the physics test resulted in the lowest mean score and thus played a minimal role in determining if a student was to be classified for admission to the university.

One of the perennial problems of the vestibular examination is that many of the tests comprising the examination are composed of open-ended questions. As one would expect, inequities often arise due to differential methods of scoring the tests. This in fact was the observation made by Vianna (142) who analyzed 161 essay tests of candidates applying for admission to the biomedical program of the Carlos Chagas Foundation in

São Paulo. The essay test was one of a battery of tests given to the candidates. An analysis of variance showed that there was a significant difference in the marks that four independent raters gave each of the 161 tests. It was also found that reliability scores were high for three of the four raters. Vianna's study suggests that new, objective methods of constructing and correcting the tests of the vestibular examination are needed.

Macedo (70) found that students with relatively low averages in the exact science courses taken at the Federal University of Rio de Janeiro (UFRJ) stay in residence longer and tend to enter the job market later than students with high averages. The minimum number of semesters a student is required to stay in residence is four, while the maximum number is eight. Macedo explains his findings by analyzing the specialties of the students and the selection process by which they were admitted to their respective departments. He writes that when taking the vestibular examination a student applies for one of the following areas in the exact sciences: engineering, chemistry, chemical engineering, physics, geosciences, or mathematics. Once the student passes the examination he is usually arbitrarily assigned a specialty. Thus, a student who has successfully applied for the geosciences area might be assigned to the astronomy, geology, or meteorology department. Later in the course of his studies, he may change specialties. As Macedo observes, such a procedure often results in anomalies that are

difficult to correct. For instance, more students apply for the few vacancies of prestigious specialties, such as engineering than for the vacancies of less prestigious specialties, such as physics or chemistry. Consequently, the caliber of student is uneven for the various specialties and this invariably results in an uneven quality among the various programs. In relation to his study, Macedo concludes that because more students apply for the prestigious professions the competition for admission is fiercer and thus only highly qualified students are admitted. Once in the program these students generally show high averages, are sought out by industry sooner, and thus spend only the minimum time necessary in the university to fulfill their residence requirement.

Freitas (49) found that a student's high school preparation is related to his performance on the vestibular examination. In an ex post facto study, Freitas observed that of 205 agronomy students of the Federal Rural University of Pernambuco (UFRP), the 33 students who were prepared in agricultural high schools obtained significantly higher means on the vestibular examination than the 172 students who were prepared in non-agricultural high schools. The differing levels of performance were sustained during the first three years of the university after which they leveled out. No explanation was given for this phenomenon.

Finally, Lucena (69) reports on a project of the Physics Department of the Federal University of Rio Grande do Norte (UFRN) in Natal to transmit physics lectures to secondary school students studying for the vestibular examination. The project

was designed to oriente the students who intended to specialize in physics. The half hour televised lectures, which included lectures, laboratory demonstrations, and problem solving exercises, were judged successful on the basis of informal evaluations. It was observed, for instance, that the science texts which were used in the lessons sold briskly in local bookshops, and that in a selected sample of students, more individuals watched the televised physics lectures than the other televised program scheduled at the same hour.

Fact-Finding Surveys

Apart from studies conducted on the vestibular examination, several researchers have conducted surveys to determine the state of physics teaching in the basic cycle of the university. The basic cycle refers to the mandatory courses required of all first year science students, regardless of their area of specialization. Terrazan (129), in a questionnaire sent to 38 federal, state, and private universities acquired data on both the theoretical and the experimental teaching of physics in the basic cycle. The major findings of his survey were the following: (1) On the average, 4 1/2 hours of theory were programmed each week. The variation was between 3 and 6 hours. (2) The sizes of the physics classes were relatively large. While 52 percent of the universities reported section enrollments of between 20 and 50 students, 24 percent reported section enrollments of 50 to 80 and of 80 to 100 students, respectively. (3) Of 440 physics instructors surveyed, 45 percent possessed an under-

graduate degree, presumably a Bachelors of Science; 8 percent possessed a doctors degree, 9 percent a masters degree, and 22 percent were monitors who assisted the professors. It should be noted that the small number of instructors with graduate degrees becomes even smaller when one considers that 40 percent of the master degree and 47 percent of the doctor degree instructors were members of the faculty of the University of Campinas. (4) Approximately 17 percent of the universities reported that no formal coordination existed between theoretical classes and the laboratory program, i.e., students were not taught theoretical concepts before doing corresponding laboratory experiences. (5) On the average, 2 hours of laboratory were scheduled per week, with a variation between 0 and 4 hours. Terrazan points out that the number of hours of laboratory in the Brazilian university is small in comparison to the 4 hours per week offered in American universities and the 6 hours per week offered in English universities. He also observes that such a limited number of laboratory sessions cannot possibly develope a student's experimental skills since the average Brazilian high school student has little or no contact with the laboratory before entering the university. (6) In general, the number of students in the laboratory sections were small. Approximately 63 percent of the schools reported sections of 10 to 25 students; 19 percent of 25 to 35 students, and 18 percent of 35 to 50 students. (7) The average number of students comprising a laboratory team vacillated between 3 and 4, with 5 to 6 students per team not being uncommon. Apparently, the

scarcity of laboratory equipment accounts for such large laboratory teams. (8) The majority of the laboratories in the universities were between 1 and 5 years old, with a small percentage being between 5 and 10 years old. (9) The two problems of laboratory teaching most indicated by the physics departments were, first, a scarcity of laboratory materials, and second, a lack of qualified laboratory instructors. In general, the results of the Terrazan survey show that while the theoretical classes in the physics departments of Brazilian universities appear reasonably well managed, laboratory sections are generally understaffed, underequipped, and overcrowded.

In a study by Saad (99), 47 institutions of higher education were surveyed to collect information about laboratory teaching in physics. Saad found that in both gross numbers and the percentage of laboratory experiments programmed, the greatest number of activities was on the subject of mechanics, with electromagnetism, optics, and heat following in that order. Saad also found that on the average 6 laboratory experiments were programmed each semester and that they were generally intended to achieve one or more of the following objectives: (1) to instruct students in the use of instruments such as micrometers and voltmeters, (2) to experimentally verify physical laws, and (3) to develope theoretical concepts introduced in lectures.

Santos (102), in a questionnaire applied to students enrolled in the general introductory physics courses of UFRN, found that the majority of students chose civil engineering or

electrical engineering as their preferred area of specialization. In most cases physics, chemistry and biology were relegated to second or third choices. In fact, only 5 percent of those enrolled in the courses had chosen physics as their preferred specialty. Santos concludes, as did Macedo earlier, that the engineering profession is a more prestigious and lucrative line of work when compared to the standard science professions. It was also found that 80 percent of the students interviewed carried more than 25 credits per semester and that 70 percent carried extracurricular work loads of 20 hours or more. Santos suggests that the debilitating effects of heavy course loads and distracting extracurricular activities has been one of the causes for a high attrition rate among students in the physics specialty.

Two fact-finding surveys were not discussed because of the highly specific nature of the findings. Campos (25) interviewed students and professors of the Faculty of Medicine of the Federal University of Minais Gerais (UFMG) to obtain information which would be used in modifying the medical curriculum. Timo-Iaria (130) reported on the courses, number of students, and professors in the physiology and the biophysics programs of several Brazilian universities.

Laboratory

The Terrazan and Saad surveys showed that laboratory teaching in the physics departments of many universities suffer from a scarcity of materials and of qualified teaching personnel.

Brazilian educators are well aware of these problems and so it is not surprising to find the literature filled with suggestions on how to construct laboratory instruments such as an optical spectrometer (Mammana, 71), an electric motor (Steiner, 122), a sand clock (Santos, 105), and a sun dial for studying the properties of light (Harter, 62). Suggestions have also been made for conducting simple experiments that require inexpensive materials, such as rubber balls for investigating the properties of collisions (Harter, 61), an icebox for illustrating the laws of thermodynamics (Takeya, 127), water drops for studying the trajectories of flying objects (Silva, 118), and air matresses for studying inertial and angular momentum (Schreiner, 108). Several Brazilian educators have also proposed entire laboratory programs that are simple and that require inexpensive materials. Almeida (3), for instance, proposes a laboratory program that consists of materials for conducting experiments on electricity in solids and that can be performed easily by laboratory teams of five students. Also, Schiel (107) describes a set of laboratory equipment for studying optics.

Several Brazilian educators have made more dramatic suggestions for improving laboratory teaching. Nakamura (81), for example, purposes a set of instructional packages for teaching students techniques of the chemistry laboratory such as handling laboratory instruments and performing experimental operations such as determining the melting point of a substance. Gomes (56) describes a laboratory program in which final

examinations are eliminated and student-selected research problems are substituted in their place. Similarly, Toledo (131) suggests that student learning in biochemistry courses can be enhanced by student-teacher interviews for the theory classes, and for the laboratory classes, by simple research projects destined for publication. Azevedo (16), in an effort to integrate theoretical classes and laboratory sessions, proposes that problems at the end of physics textbook chapters be coordinated with laboratory sessions. Finally, Tabak (126) writes that in the University of Araraquara in Sao Paulo, students are expected to complete a monograph on a research problem as part of their graduation requirements in the chemistry department. Tabak argues that the universal adoption of this policy by Brazilian universities would insure that proficient science researchers be produced to meet the needs of national development.

Individualized Instruction

In the review 49 studies were identified that discussed or presented data on some form of individualized instruction. A quick look at some of the individualzied instruction programs that are being implemented reveals some interesting developments of science teaching on the university level. There are, for example, reports on the elaboration of programmed textbooks in chemistry (Chauvin, 36; Paixao, 89), physics (Vilani, 143), and population genetics (Carvalho, 32). Nakamura (81), who was cited earlier, describes the development of instructional

packages for teaching chemistry laboratory techniques and Mozeto (80) describes a set of instructional packages for teaching crystaline and molecular structure. Also, Angotti (8) reports on the development of modules to teach the concept of relativity and Nale (82) describes a method of using case histories to teach the notion of "prediction" in a programmed course in biology. Finally, Colli (37) describes a set of modules developed in the Faculty of Medicine of Catandrua to teach students about such topics as anemia, pregnancy, and diarrhea.

It must be admitted, however, that the most popular form of individualized instruction in Brazil today is the Keller Method of Personalized Instruction. The Keller Method was introduced into Brazil in 1964 by Fred Keller, Rodolfo Azzi, and Carolina M. Bori in the pscyhology classes of the University of Brazilia. In 1969, it was introduced into the engineering schools of USP and UFRJ. Buchewitz (24) adds that the Keller Method was introduced into the physics department of USP in 1973. Since that time, Buchewitz notes, several research projects and three masters theses at USP have been based on the method. The extent to which the Keller Method has influenced science teaching at USP is illustrated by the fact that between 1973 and 1975 approximately 1300 students, 27 professors, and 118 monitors participated in physics courses based on the method. The moviment to adopt the personalized method of instruction to university

teaching is further illustrated by Serpa (114) who describes physics courses of the University of Brazilia that were taught by the Keller Method. The courses, which were given in 1969 and 1970, serviced more than 1500 students. Cesar (35) and Boures (20) also report on personalized instruction courses in their respective universities.

While many Brazilian educators feel that the Keller Method of personalized instruction is an appropriate strategy for circumventing some particularly disconcerting problems of science teaching on the university level, research on the avowed benefits of the method have generated mixed results. On the one hand there are studies like those of Levandowski (67) and Buchewitz (23) that show that the Keller Method combined with audiotutorial techniques can serve as a viable alternative to traditionally taught science classes. Likewise, Serpa (112) and Serpa (117) have found that in comparison to the lecture and small group methods of teaching, the personalized method of instruction was more efficient in reducing the learning differences of students of varying socioeconomic backgrounds.

Other research studies, however, have shown that the Keller Method offers few advantages over alternative forms of teaching. More specifically, Dionisio (40) observed that the "level of learning" of a Keller Method instructed physics class did not differ significantly from a traditionally taught class. Moreira (78) reports no significant difference in retention of learned material by students in Keller Method and traditionally taught classes. Finally, Quintas (95) compared the performance

of physics students taught by lectures, group discussion sessions, and personalized instruction techniques, and found that according to Nedelsky's taxonomic definitions, students taught by the lecture method mastered "knowledge" material more efficiently that students taught by the other two methods. However, no significant difference was found among the three groups in the mastery of "comprehension" material.

Even though Brazilian educators do not seem to agree upon the merits of the Keller Method in terms of student gains in achievement, there does seem to be, as both Bezerra (18) and Buchewitz (22) demonstrate, a general consensus among professors, monitors, and students who have been exposed to the method that it is enjoyable and that it can potentially improve student performance in areas that are not often evaluated.

In general, much of the thinking about the advantages of the Keller Method is typified in the conclusions drawn by Iida (63) about the benefits of an engineering course taught by the personalized instructional mode: (1) the students were able to program their own studies, (2) the workload of the professor was more uniformly distributed, (3) the volume of concepts transmitted surpassed the usual volume taught under traditional methods, (4) the students' capacity to verbalize was improved, (5) evaluations were more just, and (6) the student-teacher relationship and the social environment were improved. No empirical data was provided in the abstract to substantiate these claims.

Teacher Training

A final and important topic of discussion is teacher training. Essentially, there are two types of teacher training programs in the Brazilian university. The first is a four year program that prepares preservice teachers for traditional science disciplines in the secondary schools. The second is a three year program that prepares preservice teachers to teach science in grades five to eight on the primary level. Teachers destined for the first four years of the primary school are prepared in either three or four year normal schools.

The four year teacher training program typically consists of professional content courses in the student's science specialty and several education courses such as educational pscyhology, teaching methods for either the primary or secondary school, laboratory teaching methods, and supervised practice teaching. In the three year program there is also a heavy dose of professional content courses; however, they are not confined to one science specialty. The general science nature of the program is considered suitably apt for the teaching requirements of the primary school. The education courses are basically the same as those in the four year training program.

One of the teacher training courses most discussed in the literature is the laboratory methods course. Because of the inadequacies of laboratory teaching on the primary and secondary levels, many Brazilian educators consider this course essential for the preparation of science teachers. Pacca (87)

Lucena (68), Kwasniewski (66), Haumburger (59), and Veira (140) attest to the fact that there is a diversity of opinion on how the laboratory methods course should be taught. In some universities, for example, the course ignores methodology altogether and focuses instead on teaching physics content. In other universities, the course is found to concentrate on teaching the methods of teaching physics. Finally, some universities program the laboratory teaching methods course to analyze the philosophy and structure of national and international science curricula such as PSSC, PEF, FAI, and PREF for physics, and BSCS for biology. Little wonder that some educators advocate standardizing the course, if not on a national level, at least on a state level.

Several studies reported on programs for instructing preservice teachers in the proper methods of teaching science on the primary or secondary level. These reports show that there exists a fair degree of sophistication in many of the teacher training programs in Brazilian universities. Dominguez (42) reports on the use of videotapes to formatively evaluate the behaviors of preservice chemistry and physics teachers at the Federal University of San Carlos (UFSCAR). It was observed that feedback on personal and group behaviors resulted in significantly improved teaching performance in the second semester of the course. Carvalho (30) reports using videotapes in conjunction with the Flanders Interaction Analysis Categories system. These combined training techniques successfully reduced

didactic exposition and significantly increased the number of questions asked by the students and the practicing teachers. In subsequent yet unrelated studies, Carvalho (28,29) describes a practice teaching course in which preservice teachers taught mini-courses, or modules, that lasted approximately 14 hours each. Topics such as Ohm's Laws, Newton's Laws, Electric Motors, Graphs, and Free Fall were discussed in the mini-courses. By means of a student questionnaire Carvalho was able to ascertain that the mini-courses were considered most successful by the students when they complimented existing content taught during regular classes in the school, rather than when they served as remedial courses.

Summary

The studies reviewed in this section were numerous and covered a diversity of topics, and therefore, provided a panoramic view of science teaching on the university level. The fact-finding surveys indicated that the average introductory physics course of the Brazilian university is afflicted by a scarcity of laboratory materials and qualified laboratory instructors. It was shown that these difficulties have prompted many educators to suggest simple and inexpensive laboratory materials which can be easily fabricated, as well as simple experiments which utilize such materials.

Teacher training programs were shown to consist of courses of uneven quality. This was observed to be the case for the

laboratory methods course which prepares students to teach laboratory programs on the primary and secondary level. The regular science methods courses, however, were found to be of high quality. It was also shown that individualized instruction is the most popular teaching approach in university science courses.

An Overview of the Research Conducted

In the previous sections science education research contributions for the years 1972 to 1977 were reviewed. In this section some general conclusions about the overall state of Brazilian science education research are presented.

Science education research reports and studies are communicated primarily through national conferences. In compiling the studies for the review, seven national education journals were consulted and 27 articles related to science education were identified. The small number of articles found in education journals can be contrasted to the 81 abstracts of studies presented at the annual meetings of the SBPC and the 115 abstracts of studies presented at the 1974 and 1976 meetings of the ABF. The reason for this disparity is that there are few nationally prestigious educational journals that report research conducted on the teaching of an academic subject. The only journal of consequence that includes such studies is Cadernos de Pesquisa which is published by the Carlos Chagas Foundation in Sao Paulo. The only journal that regularly reports studies on science teaching is the Revista Brasileira de Fisica which is

published by the ABF.

Graduate schools of education are contributing little in the way of science education research. One of the sources consulted for the review was the Catalogo do Banco de Teses which is published by the/MEC. The theses bank catalogue is a document that contains abstracts of master and doctor degree theses for the years up to and including 1976. Of the 177 abstracts in education, eight / theses on science education were identified for the years 1971 to 1976. Four of these, however, were on health and agricultural teaching. Also, four science education theses originating in physics graduate programs were identified. The total of twelve theses accounts for 6 percent of the number of studies reviewed.

The small number of theses emanating from the nineteen graduate programs in education is due to the fact that most of the programs were instituted in 1972. The recent origins of graduate education has certainly been a limiting factor on the quantity and quality of theses being produced. The fact that there are no specializations or specialized courses in science education / (MEC, 155) further limits the number of theses dealing with science teaching.

Science education research is primarily directed towards the university. One hundred and seventy-one studies, or approximately 73 percent of the studies reviewed, dealt with issues of importance to university science teaching. The fact that many of the studies were descriptions of undergraduate science and teacher training courses indicates that the majority

of university-level science education research is being conducted by professors of undergraduate programs.

There were only 15 studies that dealt with issues of relevance to science teaching on the primary level, and at least half of these were fact-finding surveys. As for research on the secondary level, only 47 studies were identified. This group of studies was primarily composed of descriptions of national science curricula. Few course and program descriptions were reported.

Science education research is dominated by studies in the area of physics. Apart from the SBPC, the only professional organization that regularly communicates research findings on science teaching is the ABF. The Assocation publishes a journal entitled the Revista Brasileira de Fisica, which reports on research conducted in physics as well as a small number of studies in science teaching, and meets biennially in national conferences during which studies on the teaching of physics are presented. For the review, 14 studies from the journal and 115 studies from the 1974 and 1976 ABF meetings were identified.

The predominance of the ABF and exceptionally strong physics departments at the University of Brazilia and USP have made the study of physics teaching the prime research topic in Brazilian science education. A total of 151 studies were on some aspect of physics teaching while only 24 and 33 studies, respectively, were on chemistry and biology teaching. The remaining studies dealt with such assorted disciplines as

geology, astronomy, and general science. In terms of the available published literature, science educators in physics are contributing much more than science educators from other disciplines.

The majority of science education research is being conducted by a small number of universities. Forty-five institutions contributed studies on science education to the review. Twenty-four of these were private and public foundations, vocational and teaching centers, and elementary and secondary schools. The remaining 21 institutions were centers of higher education.

It was found that the 21 universities accounted for 191 studies, or 81 percent of the total number of studies reviewed. It is interesting to note that USP contributed 73 studies to this total while six other institutions: UFSCAR, UFRGS, UFMG, UFRJ, the University of Campinas, and the University of Brazilia, contributed 82 studies. This elite network of universities, with USP at its head, produced two-thirds of the studies for this review.

Foreign educational thinkers have had a small impact on science education research in Brazil. Several foreign educational models and theories were used in Brazilian science education research. As indicated previously, Keller's method of personalized instruction is perhaps the most widely adopted foreign innovation in Brazilian science education today. Second, is Bloom et al.'s Taxonomy of Educational Objectives. Typical of the use made of the taxonomy are studies like those of Buchewitz

(21) who analyzed the scores on items of multiple choice and essay tests and Arruda (13) who categorized content matter in a teaching unit of physics, both according to the levels of the taxonomy.

Several studies adopted Nedelsky's scheme of objectives as stated in Science Teaching and Testing, while one study used Klopfer's taxonomy for classifying pupil behavior as reported in Bloom et al.'s Handbook of Formative and Summative Evaluation. One study by Silveira (119) reported using Ausubel's theory of advanced organizers to successfully improve student performance in physics classes at UFRGS. Also, Moreira (78) interpreted the results of a successfull audio-tutorial course in terms of Ausubel's theory. Finally, two studies reported using Piaget's developmental theory. The more important of the two was conducted by Ferreira (45) who found that a sizeable number of high school and university students in his sample had not attained the stage of formal operations. These were the main theoretical contributions from foreign educators for the years 1972 to 1977.

It might be added that very few standardized instruments were used or developed during this period. There were four studies that reported using Flander's FIAC instrument, and one study, by Neto (84), that employed the Differential Aptitudes Tests to determine if teachers benefitted from an inservice teacher training course in physics. Finally, one study, by Carvalho (31), reported developing an instrument for observing the laboratory techniques of students.

Few experimental or comparative studies were reported in the science education literature. Eleven experimental and comparative studies were identified in the review. An experimental study was defined as any study that is structured according to one of Campbell and Stanley's (149) true or quasi-experimental research design , and that employed inferential statistical procedures to analyze the data. It was necessary to include this second criterion since several studies, like that of Bassi (17) which determined that a laboratory-oriented physics course was more effective than an expository course, arrived at their conclusions on the basis of a percentual analysis of criterion measures, such as the number of passing or failing students in a course.

The 11 studies accounted for 4.8 percent of the total number of studies reviewed. This percentage corroborates the findings of other Brazilian researchers who have determined that anywhere from 5 percent (Gouveia, 152) to 7 percent (DiDio, 150) of Brazilian research is experimental in nature.

An explanation for the general dearth of experimental and comparative studies in Brazilian education is partially given by DiDio (150) who writes that most educational researchers do not have the methodological and statistical backgrounds for conducting experimental research. This explains why the most commonly used research instrument in Brazil today is the survey questionnaire. The fact that most science education research is conducted by professors in science programs may also explain

why social science research procedures are not being employed in studies on science teaching. It might also be added that experimental research projects are time-consuming and difficult to set up, and they often require financial resources that are unavailable to the average university professor.

It should be mentioned that 23 studies stated a research hypothesis and employed some acceptable form of statistical analysis. One example is a study by Suman (124) who compared four types of agricultural schools in Sao Paulo in order to determine which had better teaching and laboratory facilities. Studies such as those of Rezende (97) and Hamburger (60) attempted to correlate achievement on the vestibular examination and achievement in first year physics courses. A study by Nassif (83) was a documentary analysis of the BSCS and PSSC curricula to determine if there existed a pattern in the distribution of space, figures, and written text, etc. And finally, as was mentioned earlier, there were several studies that employed Bloom's taxonomy and Flander's FIAC instrument to research a specific problem. These 23 studies, along with the experimental and comparative studies discussed earlier, constitute what we might consider to be hard core educational research in Brazil.

Science education research in Brazil is mainly comprised of course descriptions and reports on teaching innovations. Sixty-eight studies were identified as either course or program descriptions. In addition to the teacher training courses

discussed earlier, some of the university courses described were histology (Andreucci, 7), physiology (Araujo,11), pathology (Corbett,38), organic chemistry (Miranda,77), biochemistry (Toledo,131), electrochemistry (Rabockai,96), environmental geology (Arid,12), medical biochemistry (Rola,98; Vale,136), and physics courses that were either introductory in nature or that focused on a special topic such as air pollution (Orsini,85) or the development of the perceptual abilities of students (Seale,109). Also, science programs in nuclear engineering (Borges,19) and radioecology (Freitas,50) were discussed.

While the majority of the courses described were part of university undergraduate science programs, several courses and content areas in general science (Vallone,138) and ecology (Vallone,137) on the primary level were also discussed. On the secondary level, a course in mechanics (Franco,48) and an individualized instruction course in physics (Prado,94) were also mentioned.

Besides the course descriptions, there were 61 studies that suggested methods for improving science teaching and science programs. The proposed innovations covered a wide variety of topics such as constructing laboratory equipment, using the computer to monitor student progress in physics courses (Ferreira,44, Tabacniks,125) and to analyze students' responses on multiple choice tests (Abramovich,1; Telles,128), creating a question bank (Angotti,9), organizing a science

fair for primary school children (Mansur,74), and constructing audiovisual equipment (Del'Acqua,39; Domineli,41, Ferreira, 47; IFUSP,64). These are only a few of the examples of the types of innovations being suggested by Brazilian science educators.

Twenty-two position papers were also reviewed. Some of the topics discussed were the following: the value of teaching chemistry in high school (Tolentino,133; 135), the development of a program for training radioecologists for the Brazilian nuclear program (Paschoa,91), the adoption of a historical (Gordon,57; Motoyama,79) or a heuristic (Ghiotto,55) approach to teaching science, and the proposal of a research model on science teaching that employs socioeconomic variables (Serpa,116).

When the course descriptions, innovations, position papers are added to 18 curriculum studies that reported on the development of national science curricula, it was found that approximately 72 percent of the studies of the review did not state a research problem or hypothesis, nor require statistical analyses.

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